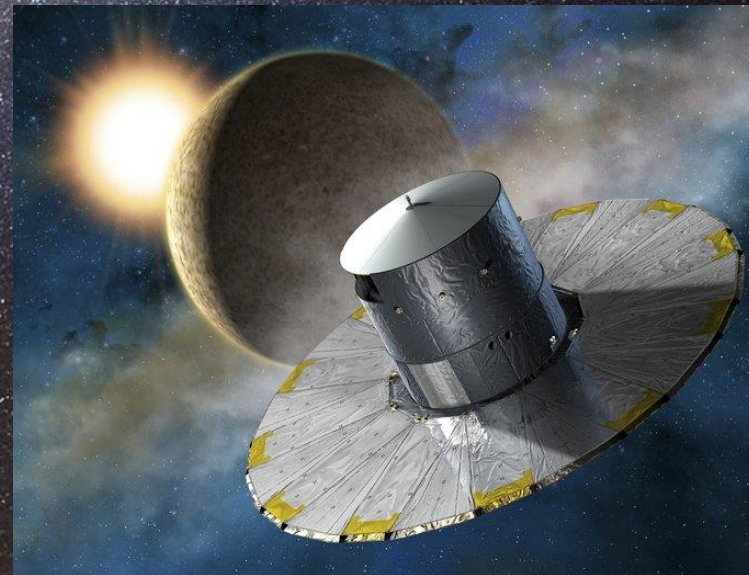
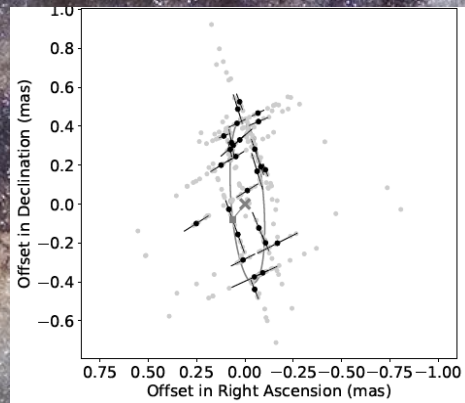


Toward DR4: Preparing for Gaia's First Exoplanet Catalog



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Gaia Observations Are Ending...

- ...On January 15th!
- As today, Gaia has been in operation for 3823 days, gathering 140,968 GB of science data for a total of 267,225,340,030 transits observed
- Gaia will be passivated in March/April 2025...
- ...but we are far from the end of the Gaia mission!

Gaia DR3 Astrometry & Exoplanets

- **Astrometric accelerations: true masses of companions**
- **Astrometric accelerations: new detections**

$$w^{(\text{model})} = w_{\text{ss}} = (\Delta\alpha^{\star} + \mu_{\alpha^{\star}} t) \sin \psi + (\Delta\delta + \mu_{\delta} t) \cos \psi + \varpi f_{\varpi}$$

- **Astrometric orbits: Doppler-detected planets**
- **Astrometric orbits: new detections**

$$\begin{aligned} w^{(\text{model})} &= w_{\text{ss}} + w_{\text{k1}} \\ &= (\Delta\alpha^{\star} + \mu_{\alpha^{\star}} t) \sin \psi + (\Delta\delta + \mu_{\delta} t) \cos \psi + \varpi f_{\varpi} \\ &\quad + (B X + G Y) \sin \psi + (A X + F Y) \cos \psi. \end{aligned}$$



gaia

Gaia DR3 astrometry:

substellar mass companions



≈ 1800 orbits



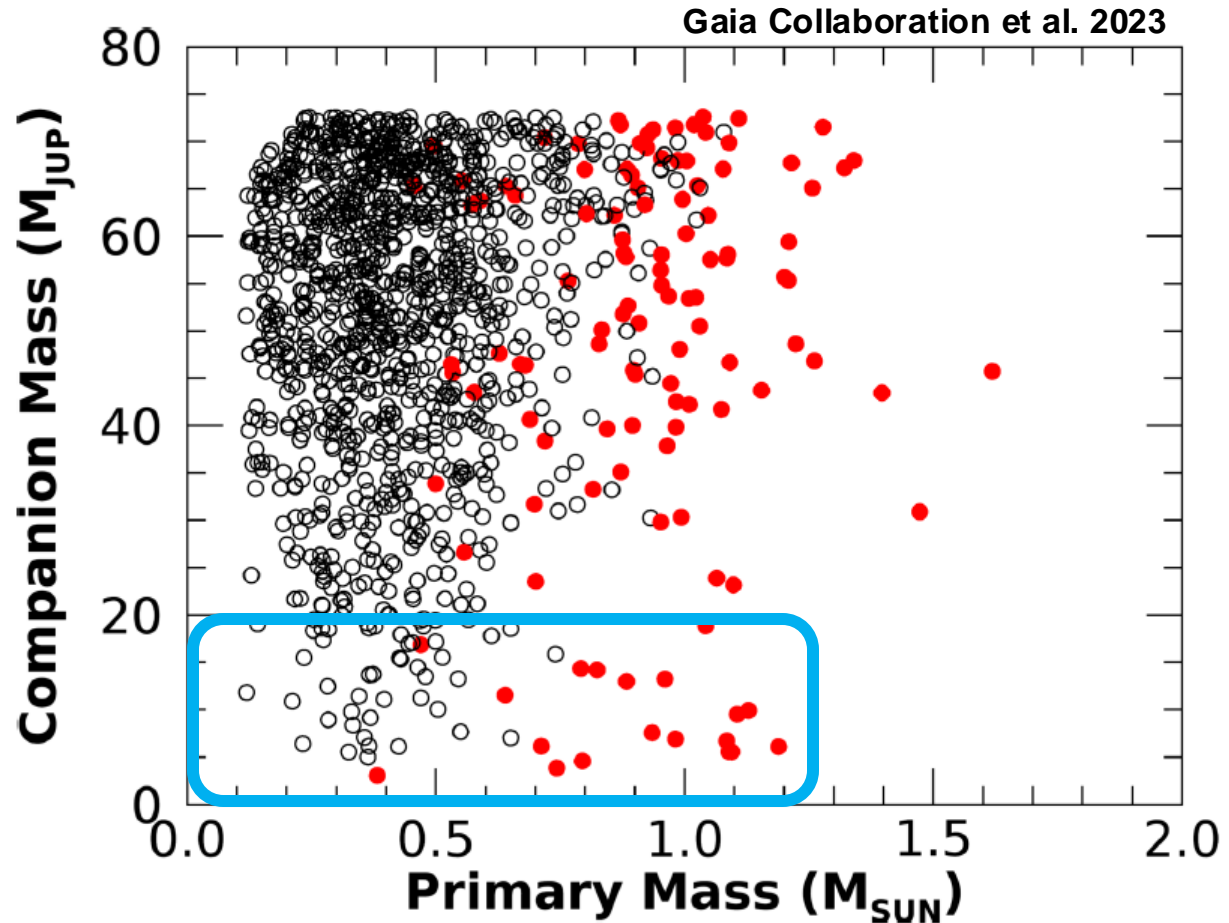
≈ 5% with $M_2 < 20 M_{\text{Jup}}$



≈ 30% with $G < 12$ mag

Typically:

- $P < 1000$ days
- $a_0 \approx 100\text{-}400 \mu\text{s}$



DR3 '(Candidate) Exoplanet List'

- Initially available at <https://www.cosmos.esa.int/web/gaia/exoplanets>
- It contains SourceID, Gaia candidate ID, Gaia confirmed ID, false positive ID, known planet ID

Gaia_DR3_source_ID	Gaia_candidate_ID	Gaia_confirmed_ID	False_Positive	Known_exoplanet
3026325426682637824	Gaia-TROI-001	Gaia-1b		
1712614124767394816	Gaia-ASOI-001			
637329067477530368	Gaia-ASOI-071			HD81040b
4955371367334610048	Gaia-RVOI-001			WASP-18b

- Must go to the Gaia DR3 archive to obtain the corresponding orbital solution from the main non-single star table, the primary mass and expected companion mass from the binary mass table, and other stellar properties from the main Gaia source table

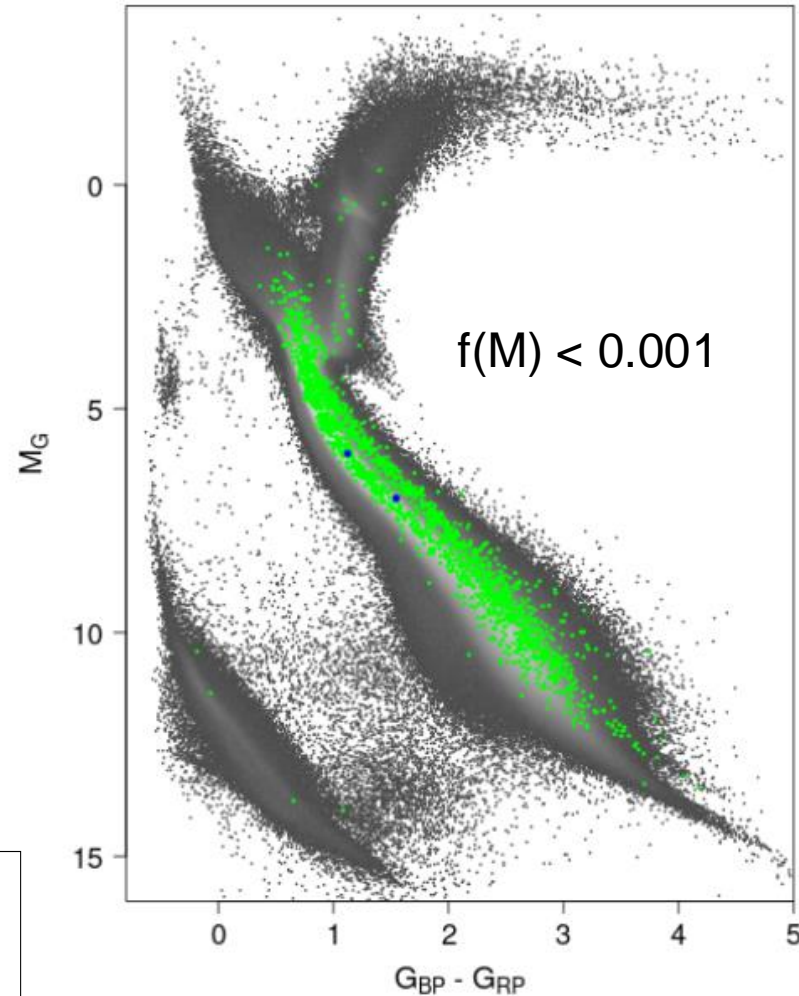
Lurking impostors...

Gaia Collaboration et al. 2023

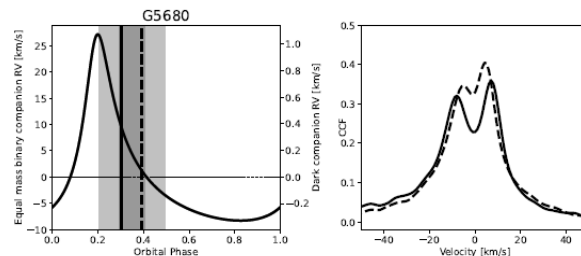
- Masses from $f(M)$:

$$(M_1 + M_2) \left(\frac{M_2}{M_1 + M_2} - \frac{F_2/F_1}{1 + F_2/F_1} \right)^3 = \frac{(a_0/\varpi)^3}{(P/365.25)^2}$$

- Small $f(M)$ \rightarrow Small M_2 ?
- False positives: $M_2/M_1 \approx F_2/F_1$



Unveiled by:
double-peaked CCFs
in high-res spectra



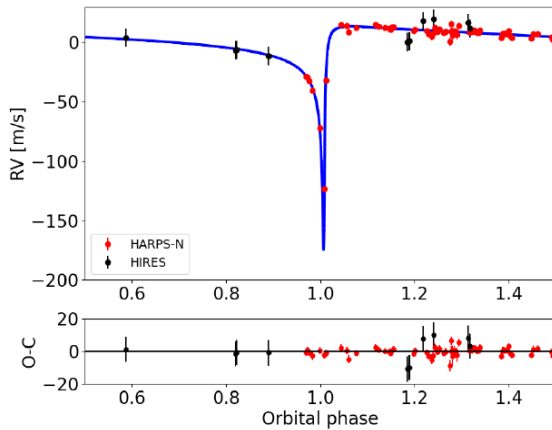
Marcussen & Albrecht 2023



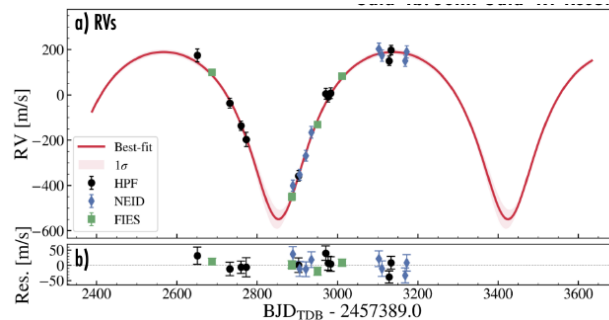
Spectroscopic Follow-up



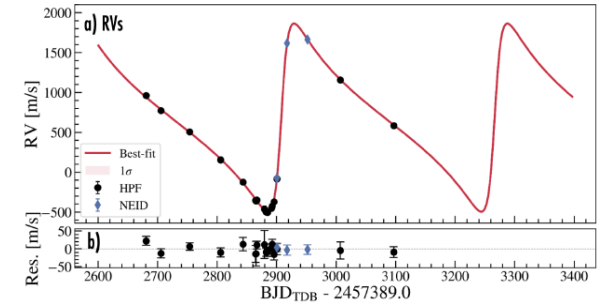
- Programs to vet the candidates (SB2 or likely planet, if not spurious)
- Programs to both vet and follow-up with RVs to refine the orbital solutions



Gaia-3b (Sozzetti et al. 2023) *



Gaia-4b and Gaia-5b (Stefansson et al. 20253)



At least 50% of candidates (around M dwarfs) are astrophysical false positives

Gaia DR4: What to Expect?

- * First of all: it won't happen before the middle of 2026
- * **From astrometry expect:**
 - >> 72 (DR3) solutions corresponding to a planet candidate
 - >> 9 (DR3) solutions corresponding to a known planet
 - Both fitted (Thiele-Innes) and derived (a , i , Ω , ω) parameters
 - A metric capturing the likelihood of false positive / true planet
 - SOME multiple solutions (two companions, one companion + accelerations)
 - MANY acceleration solutions (both first and second derivative of proper motion), SOME of which might be due to long-period planets
 - The full astrometric time-series: on average, > 600 CCD obs!
- * **Also:**
 - >> 40 (DR3) and 10 (DR3) candidate Hot Jupiters from transit photometry and RVS

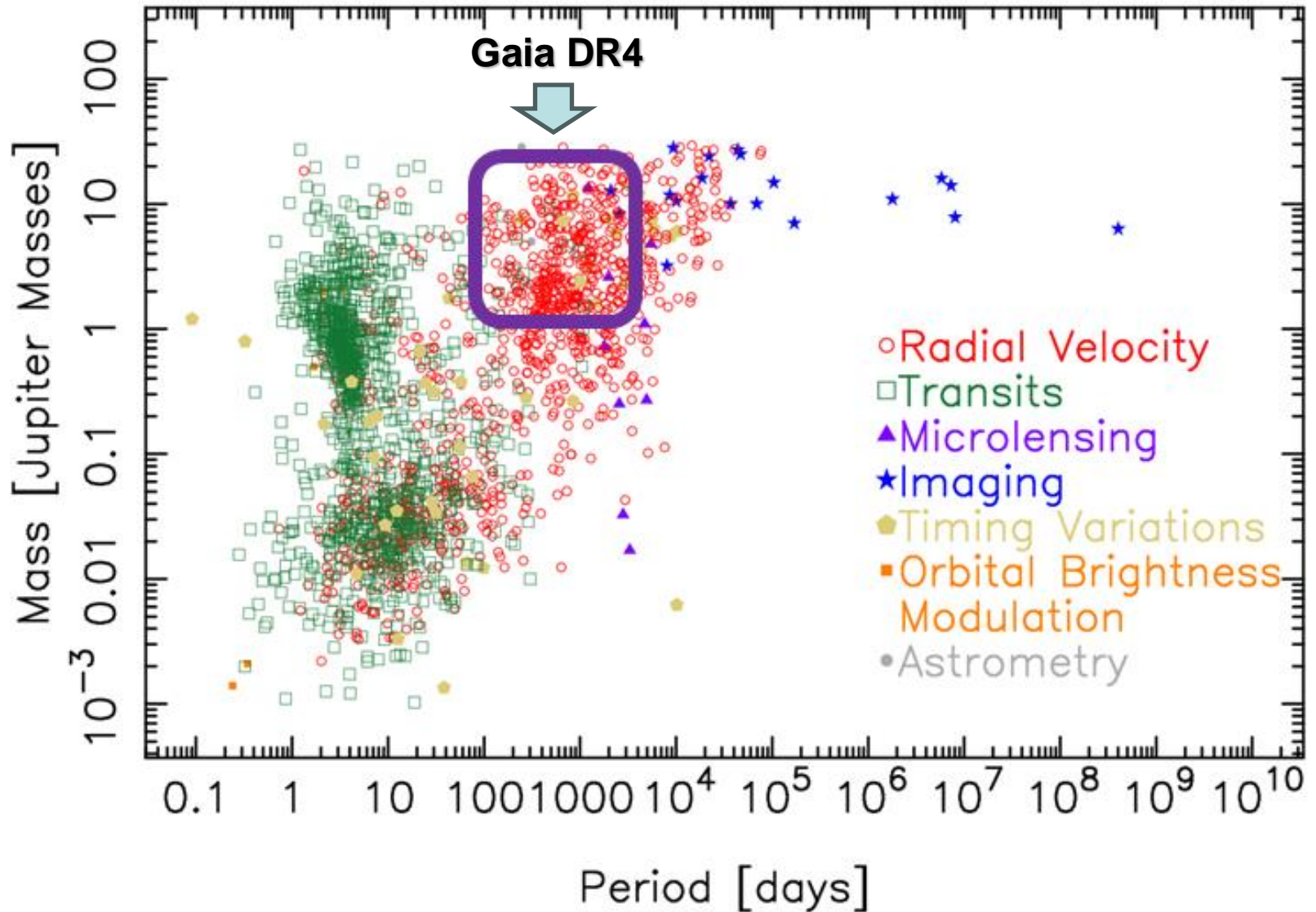
How to Access?

- There will be a comprehensive list of confirmed and candidate planets
- Complete information still likely spread among multiple DR4 tables.
- Preliminary contacts with NASA exoplanet archive and Extrasolar Planet Encyclopaedia for eventual ingestion

Mass – Period Distribution

10 Jan 2024

exoplanetarchive.ipac.caltech.edu

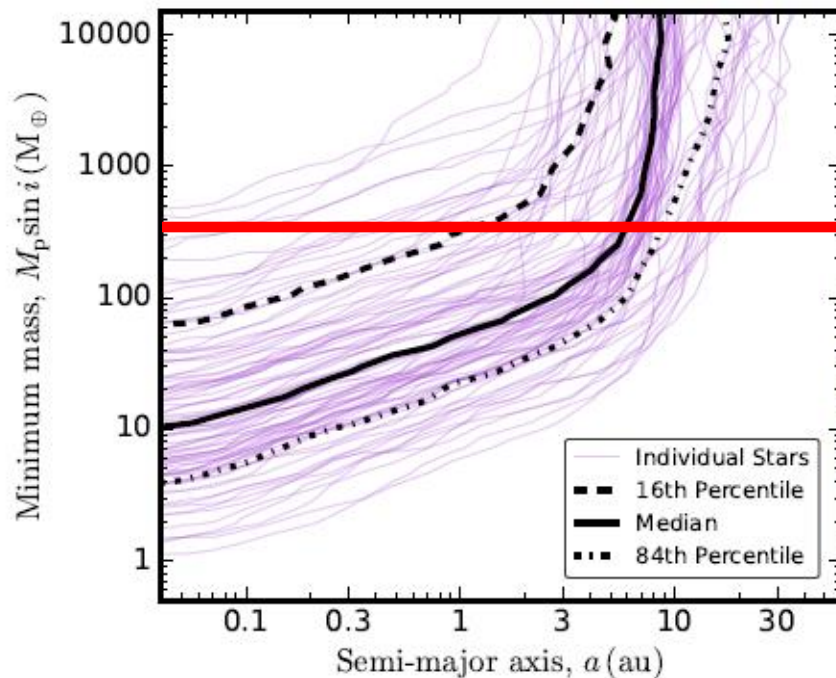


Given the catalog, what to do?

- Spectroscopy, spectroscopy, spectroscopy!
- But some high-contrast imaging too, I bet.
- Some of the follow-up efforts eased by DPAC work this time, but it will still be a very significant task
- With a large catalog of candidates, coordination of follow-up efforts desirable (Kepler and TESS FOPs instructive and successful examples)

Helping HWO (1)

- Screening the nearest (Tier1, 164) stars for ‘Jupiter signposts’ one of the critical preparatory programs (J. Becker’s talk)



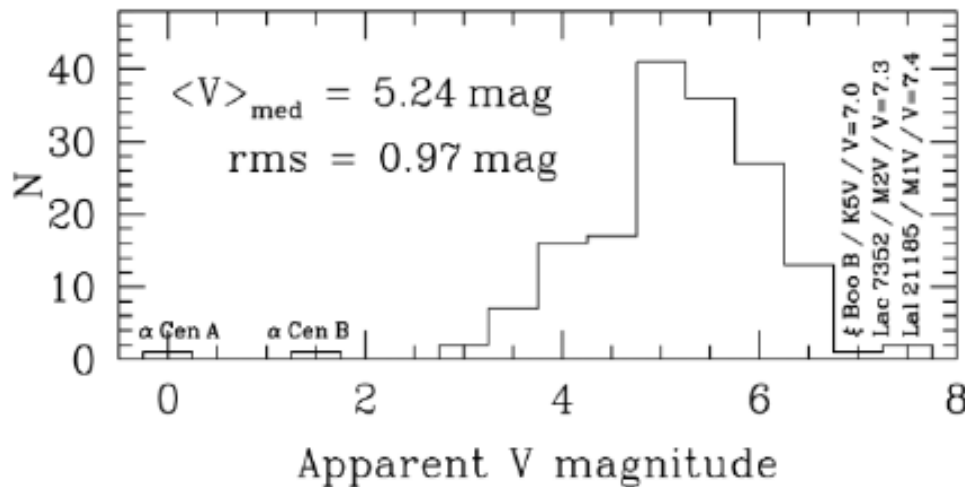
Harada et al. 2024

- Long-term RV surveys are sensitive to Jupiter analogs only around 50% or so of the sample

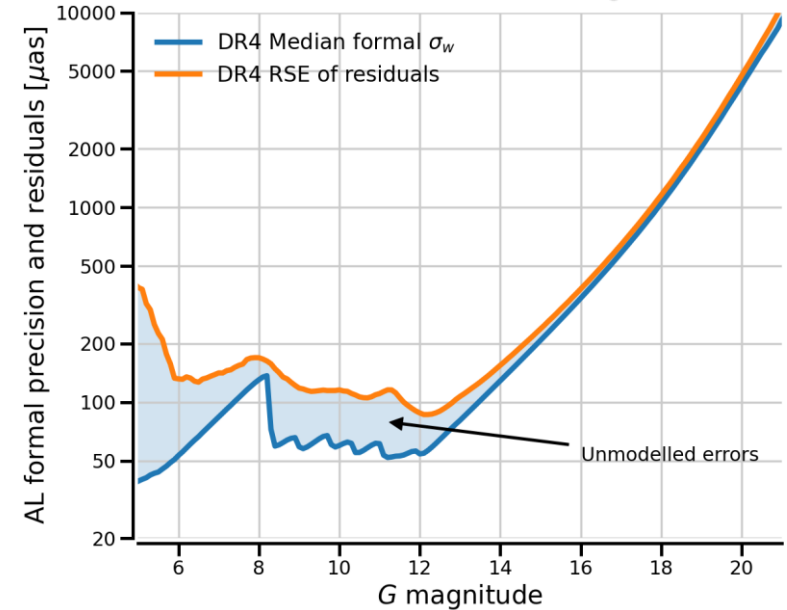
Helping HWO (2)

- The Tier 1 sample is very bright!

Mamajek & Stapelfeldt 2024



Courtesy: A. Brown



- The 10 brightest ($V < 3.5 \text{ mag}$) stars will be processed 'ad hoc'. In the range $3.5 < V < 5$, expected sub-mas precision
- That's enough for Jupiter-analog detection (primarily with DR5, well before HWO launch anyways)